2014 NORTH AMERICAN MONSOON (NAM) OUTLOOK FOR CENTRAL AND NORTHERN NEW MEXICO

Updated sub-surface TA plot (slide 2) and daily SSTA plot (slide 5) on 6/26/2014.

Looking northeast toward Santa Fe from Los Cerrillos, NM August 2, 2012. Courtesy J.D. Turner.

Attempting to predict precipitation amounts associated with the North American Monsoon (NAM) is a rather daunting task. Slight variations in sea surface temperature (SST) in the eastern Pacific Ocean and Gulf of Mexico can result in modifications to the amount of low-level moisture flux into the atmosphere. Slight variations in SSTs can also change the location of deep tropical and subtropical convection in the eastern Pacific Ocean and Caribbean Sea during the summer months, impacting where the quasi-permanent upper level high pressure dome sets up over the southern United States during June, July, August and early September. The likelihood, however, of the development of a moderate to strong El Niño make this outlook markedly more straight forward. Based on current observations, past analog years and the prospect of a moderate to strong El Niño, what might residents of central and northern New Mexico expect during the 2014 Monsoon season?

KEY CLIMATE FACTOR LIKELY TO INFLUENCE THE UPCOMING MONSOON SEASON

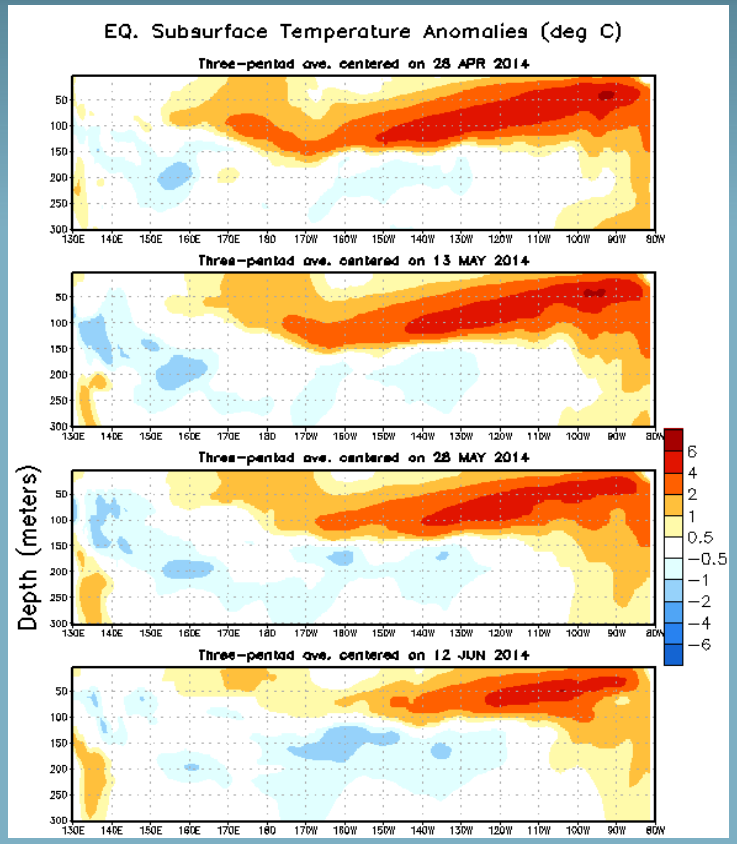


Figure 1. Sub-surface ocean temperatures in the equatorial Pacific since April 23, 2014; courtesy Climate Prediction Center. The orange and red areas indicate a very large area (equivalent to the size of the lower 48 states) of above average ocean temperatures primarily between 300 and 500 feet below the surface. The recent weakening of the positive temperature departures represents the effects of the upwelling phase of the associated Kelvin wave.

Talk of the increasing probability of a moderate to strong El Niño emerged in late winter and early spring 2014. In fact, recent observations (as of June 12, 2014) of sub-surface ocean waters in the equatorial Pacific region show a massive volume of anomalously warm water several hundred feet below the ocean surface. Very similar conditions were observed in Spring/early summer 1997, which resulted in the warmest/strongest El Niño on record.

30-YEAR AVERAGE JUL 1 – SEPT 15 PRECIPITATION VS. JUL 1 – SEPT 15 PRECIPITATION DURING STRONG EL NIÑO YEARS SINCE 1980

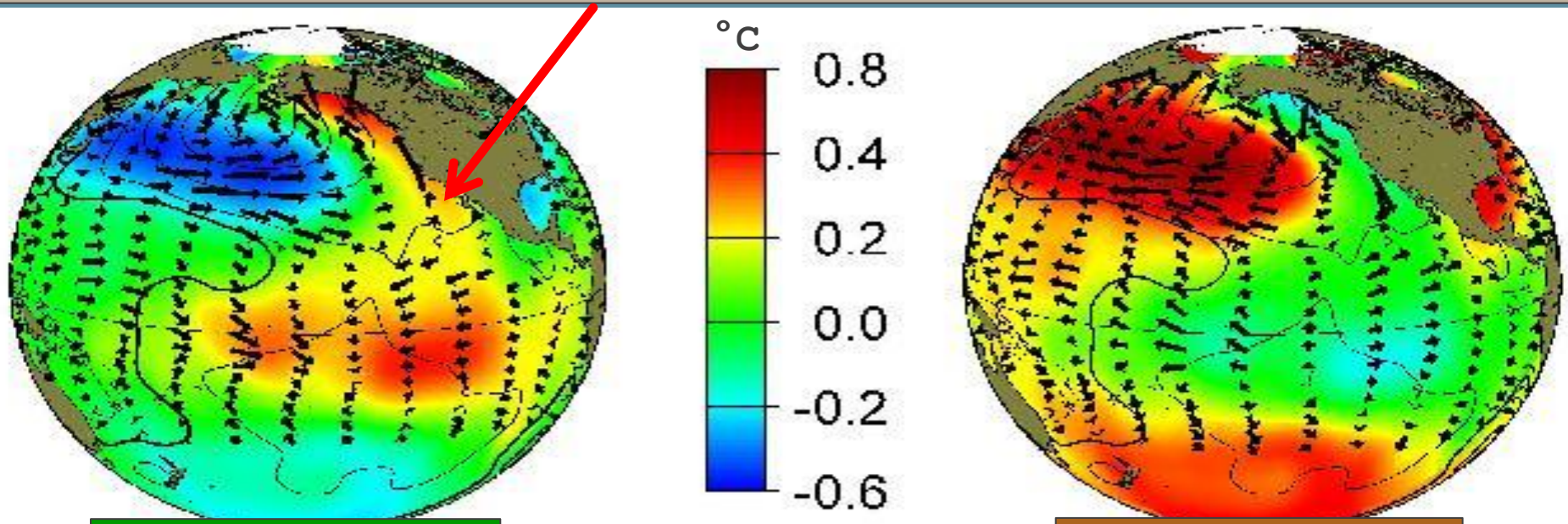
Green = Above 30-yr Avg. Brown = Below 30-yr Avg.

Site	1981-2010 AVG. precipitation (July 1 - Sept. 15)	1997 (Jul 1 – Sept 15)	1982 (Jul 1 – Sept 15)
ABQ Sunport	3.58”	4.40”	2.65”
Santa Fe	5.12	7.33	4.16
Clayton	6.73”	7.89”	9.02”
Gallup	4.60”	6.22”	6.30”
Las Vegas	7.91”	9.26”	8.73”
Roswell	4.9”	5.87”	1.99”
Chama	6.76”	7.87”	8.00”
Eagle Nest	6.43”	4.03”	9.25”
Los Alamos	7.57”	10.86”	9.05”
Taos	4.35”	5.68”	4.62”
Wolf Canyon	8.29”	11.95”	9.18”
Carrizozo	5.51”	5.72”	3.29”
Luna Ranger Station	8.59”	8.66”	7.08”
El Morro	5.82”	5.87”	6.61”

Figure 2. A comparison of the 30-year rainfall averages for the climatologically wettest period of the monsoon season (July 1-Sept. 15) to the same periods in 1997 and 1982 for select locations in central and northern New Mexico. Both of these years provide analogs which might lead us to clues about the upcoming 2014 monsoon season. 1997 and 1982 both represent the first year of strong El Niño episodes. 1982 was rather different than present day, however, as the Northeast Pacific Ocean along and near the west coast of North America remained relatively cool whereas 1997 values in this region of the Pacific Ocean were among the highest/warmest on record.

The Pacific Decadal Oscillation (PDO) and the NAM

A key factor during a positive PDO is increased low and mid level moisture availability in far northeast Pacific/Gulf of CA.



PDO values Jan, Feb, Mar, Apr & May 2014	PDO values Jan, Feb, Mar, Apr & May 1997	PDO values Jan, Feb, Mar, Apr & May 1982
+0.30, +0.38, +0.97, +1.13, 1.80	+0.23, +0.28, +0.65, +1.05, 1.83	+0.34, +0.20, +0.19, -0.19, -0.58

Figure 3. Typical Sea Surface Temperature Anomaly (SSTA) patterns and windstress (arrows) in the North Pacific Ocean during positive/negative Pacific Decadal Oscillation phases (PDO). The main difference between the two most recent (1997, 1982) strong El Niño years was the phase of the Pacific Decadal Oscillation (PDO) index. 1982 ended up as a strong El Niño but the northeast Pacific remained neutral/near average, rising slightly above zero for six months (Jan-Mar and Jul-Sept) and slightly negative/cool during the remainder of the year. In contrast, the 1997 PDO index started off much like 2014 did, slightly positive, trending up/warming in late winter and Spring.

CURRENT STATE OF GLOBAL SEA SURFACE TEMPERATURE ANOMALIES

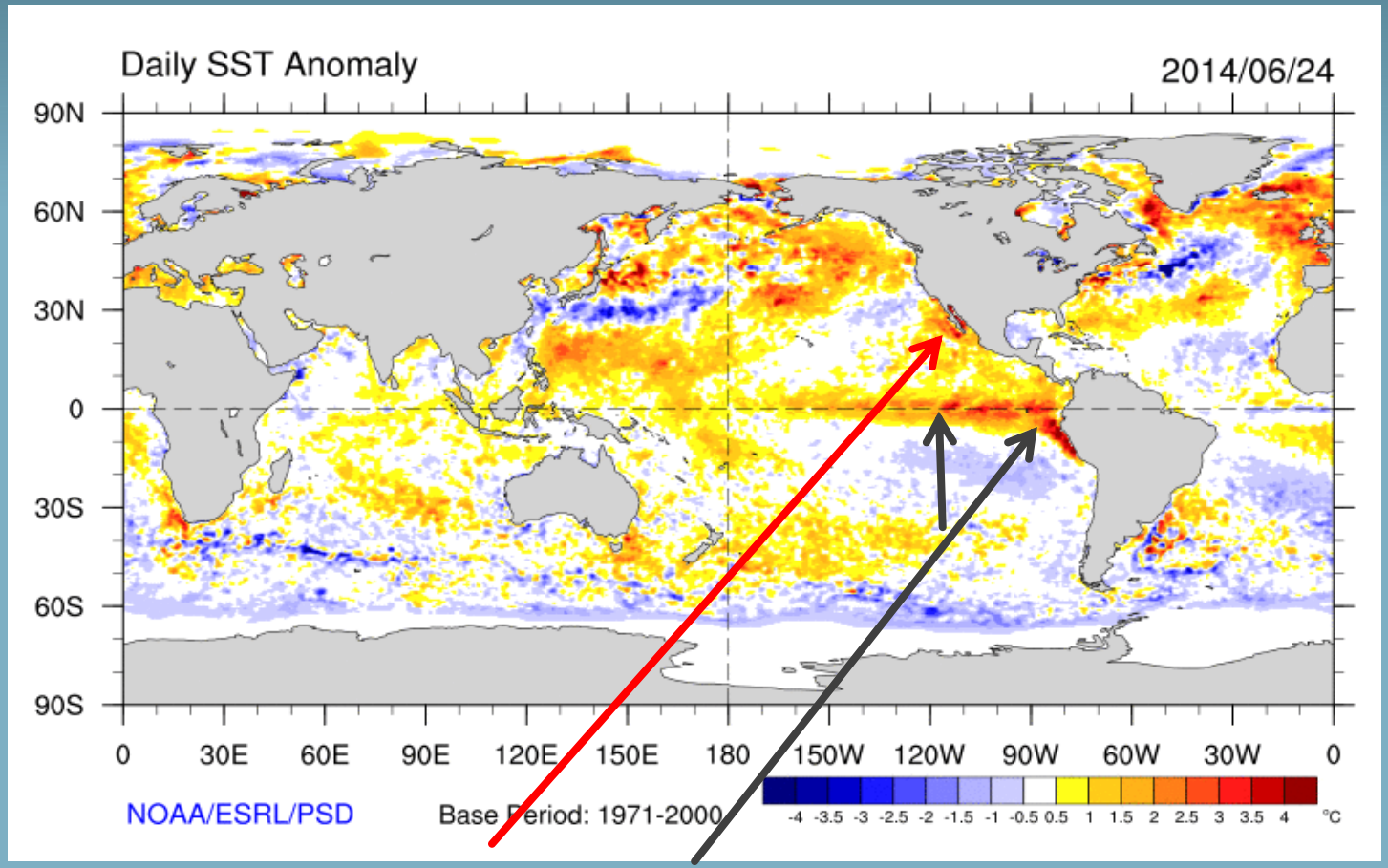


Figure 4. Global SSTAs loop (http://www.esrl.noaa.gov/psd/map/clim/sst.anom.anim.week.html) demonstrating that temperatures along the west coast of North America are have warmed and in some areas, by several degrees Celsius, which is indicative that at least a short-lived warm/positive phase of the PDO is continuing. Also notice the dramatic warming in the eastern equatorial Pacific Ocean during the past couple of days, indicative that the warmer than average sub-surface water shown on slide 2 continues to surface.

SO WHAT HAPPENS IF THIS ENDS UP AS A MODERATE EL NIÑO?

Green = Above 30-yr Avg. | Brown = Below 30-yr Avg.

Site	1981-2010 avg (Jul 1-Sept 15)	2009 (Jul 1-Sept 15)	2006 (Jul 1-Sept 15)	2002 (July 1- Sept 15)	1997 (Jul 1-Sept 15)	1991 (Jul 1-Sept 15)	1986 (Jul 1-Sept 15)	1982 (Jul 1- Sept 15)
ABQ Sunport	3.58"	3.72"	9.53"	4.61"	4.40"	7.54"	9.34"	2.65"
Santa Fe	5.12"	3.79"	8.80"	5.14"	7.33"	9.87"	5.82"	4.16"
Clayton	6.73"	9.69"	11.71"	8.18"	7.89"	16.68"	18.37"	9.02"
Gallup	4.60"	5.52"	7.75"	7.93"	6.22"	7.87"	9.92"	6.30"
Las Vegas	7.91"	10.03"	11.88"	7.77"	9.26"	15.83"	17.62"	8.73"
Roswell	4.90"	5.92"	9.62"	8.77"	5.87"	15.42"	15.27"	1.99"
Chama	6.76"	14.33"	16.18"	7.53"	7.87"	14.24"	20.33"	8.00"
Eagle Nest	6.43"	11.19"	12.64"	9.29"	4.03"	16.69"	15.98"	9.25"
Los Alamos	7.57"	13.82"	12.54"	7.60"	10.86"	18.80"	17.88"	9.05"
Taos	4.35"	3.34"	8.96"	5.21"	5.68"	13.04"	12.21"	5.68"
Wolf Canyon	8.29"	12.61"	17.40"	10.17"	11.95"	24.73"	22.70"	9.18"
Carrizozo	5.51"	5.52"	12.23"	9.34"	5.72"	12.27"	12.00"	3.29"
Luna R. S.	8.59"	12.75"	19.65"	12.12"	8.66"	13.36"	15.56"	7.08"
El Morro	5.82"	8.43"	13.98"	9.87"	5.87"	8.33"	11.74"	6.61"

Figure 5. Comparing July 1 through September 15 precipitation (climatologically wettest period of monsoon) in moderate and strong El Niño years (based on the multivariate ENSO index - MEI) with the 30-year climatological average. 2009, 2006, 2002, 1991 and 1986 were the onset years during weak-moderate and moderate El Niño episodes (based on JUL-AUG-SEPT Multivariate ENSO Index – MEI averages) while 1997 and 1982 were onset years during strong episodes. An 'onset year' is defined as having six previous months or more with negative or neutral MEI values.

THE MONSOON AND MODERATE TO STRONG EL NIÑOS SINCE 1980

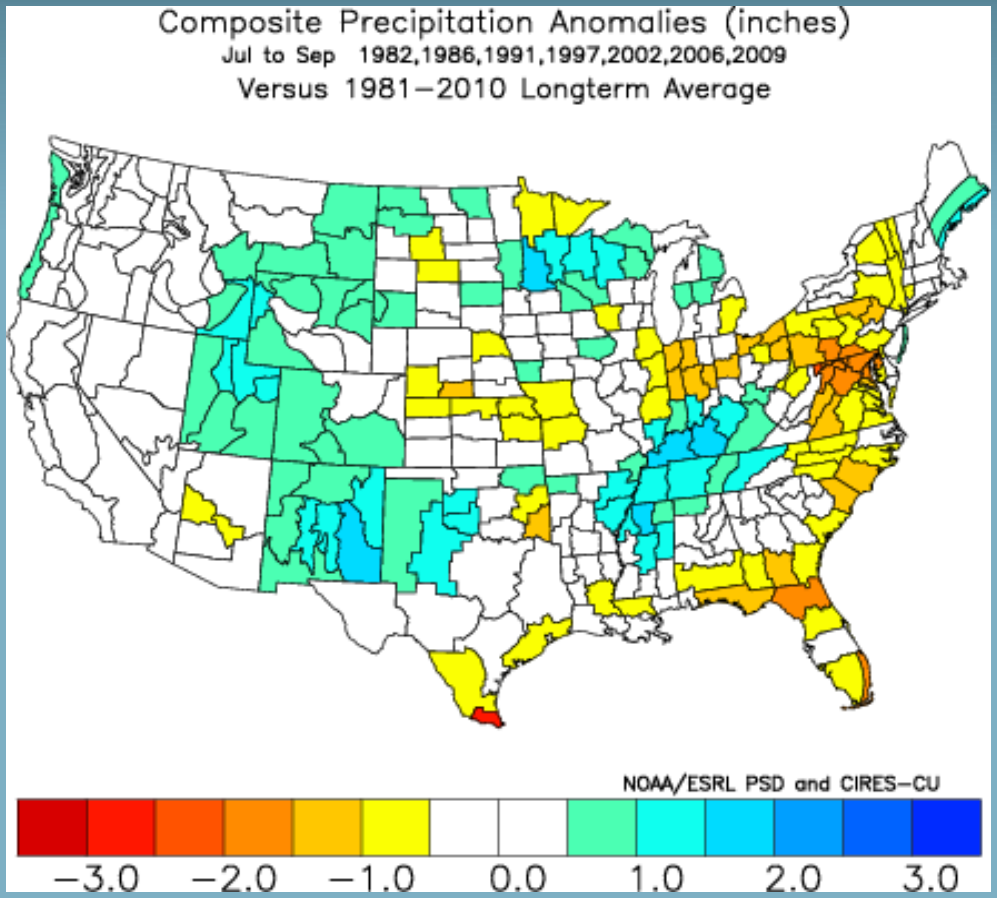


Figure 6. Precipitation anomalies between July and September during the onset year of a moderate to strong El Niño events, indicating that above average to well above average precipitation for the monsoon season was common. The borders on the map represent the Climate Prediction Center's (CPC) regional climate divisions which are defined as having similar precipitation and temperature averages.

30-YEAR PRECIPITATION AVERAGES VS. MODERATE TO STRONG EL NIÑO YEAR AVGS.

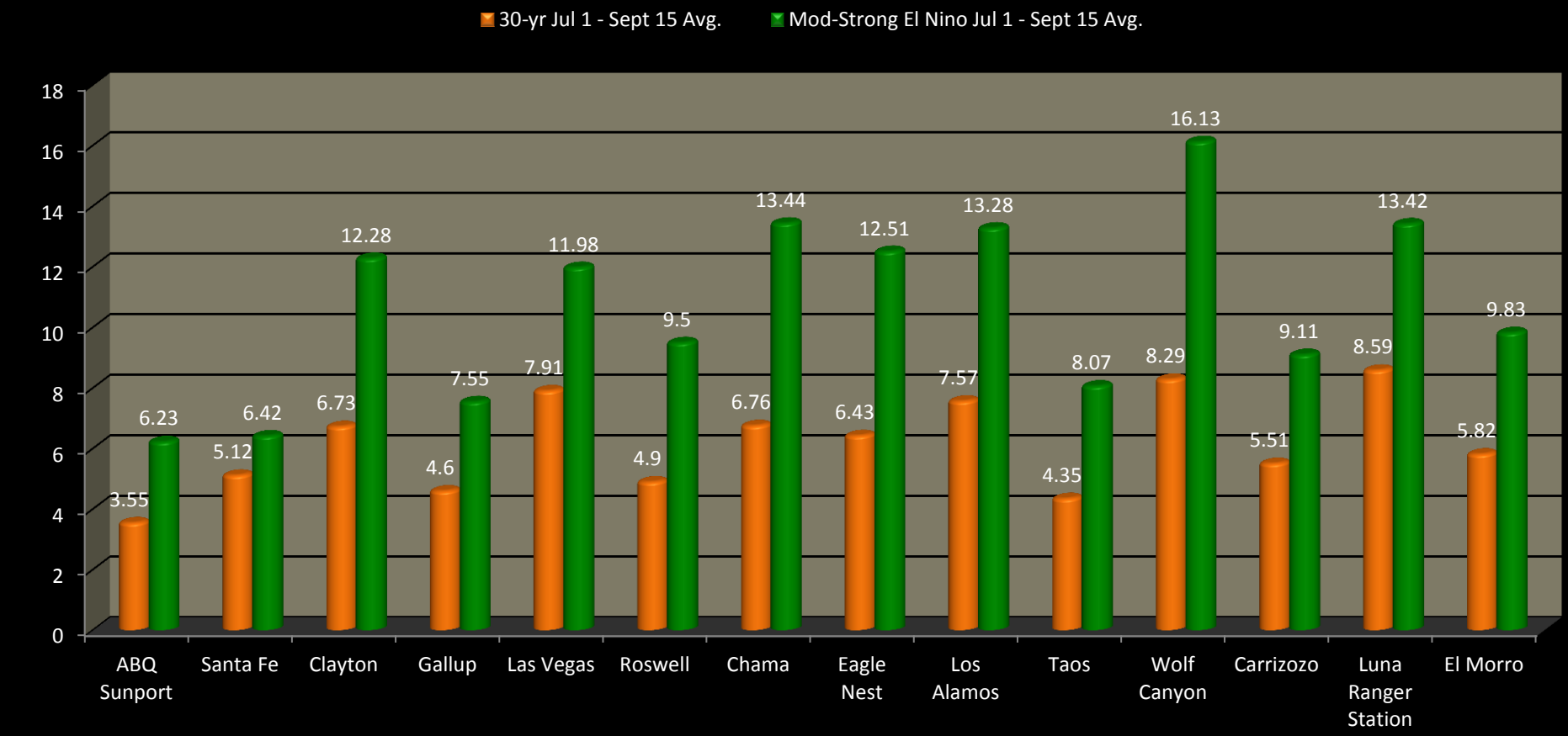


Figure 7. Comparing 1981-2010 precipitation averages to average precipitation amounts at selected sites during moderate to strong El Niño onset years from July 1 through September 15 (2009, 2006, 2002, 1997, 1991, 1986, and 1982). Note that every site is above to well above their 30-yr precipitation averages for the climatologically wettest period of the monsoon season during moderate to strong El Niño years which, if current SST trends in the Pacific Ocean continue, would favor above average precipitation during the upcoming 2014 monsoon season.

HOW IS THE GULF OF MEXICO IMPACTED BY A STRONG EL NIÑO?

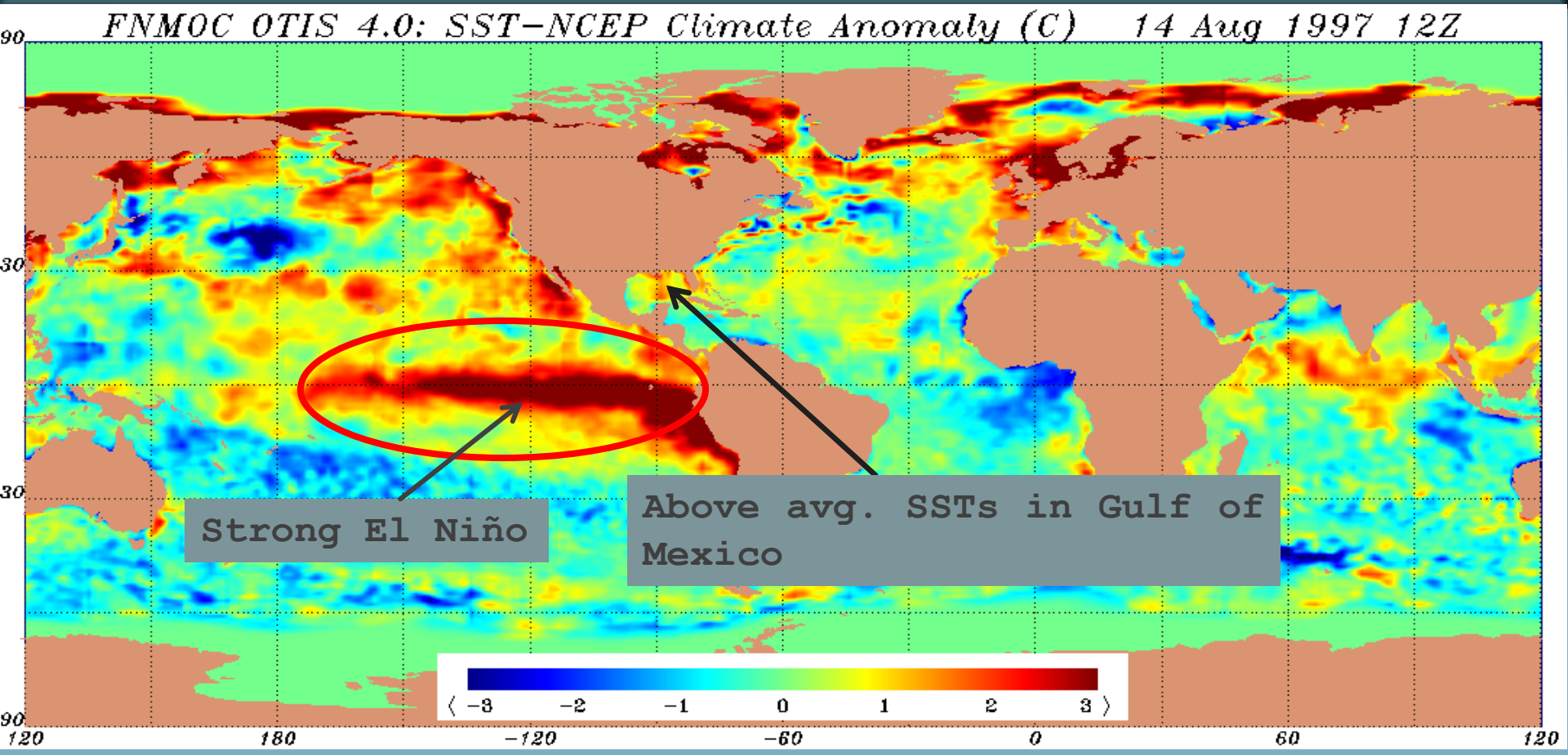


Figure 8. This image of global SST anomalies from August 14, 1997 shows a strong El Niño underway in the equatorial Pacific Ocean as well as above average SSTs in the central Gulf of Mexico. Above average SSTs in Gulf of Mexico can lead to an increased moisture availability for easterly waves or inverted troughs that occasionally move up into the state from the southeast, intermittently increasing monsoon thunderstorm activity.

WHAT ABOUT JUNE?

Green = Above 30-yr Avg. Brown = Below 30-yr Avg.

Site	30-yr Avg. (1981-2010)	2009	2006	2002	1997	1991	1986	1982
ABQ Sunport	0.66"	0.80"	1.14"	0.18"	1.21"	0.65"	2.57"	0.09"
Santa Fe	1.23"	M	0.76"	0.57"	1.50"	2.64"	2.26"	0.15"
Clayton	2.08"	1.71"	1.18"	0.97"	2.02"	2.66"	1.97"	2.99"
Gallup	0.51"	0.93"	0.37"	T	1.21"	1.76"	1.06"	0.05"
Las Vegas	2.22"	1.34"	1.58"	0.67"	2.69"	2.07"	3.83"	2.55"
Roswell	1.73"	0.65"	1.31"	3.62"	0.69"	1.24"	5.02"	0.76"
Chama	1.09"	3.13"	0.71"	0.00	1.62"	1.63"	1.47"	0.06"
Eagle Nest	1.36"	1.58"	1.01"	1.06"	1.32"	1.88"	3.80"	1.27"
Los Alamos	1.52"	2.67"	1.78"	1.91"	1.91"	1.71"	5.67"	0.15"
Taos	0.94"	M	M	1.02"	1.16"	1.58"	2.24"	0.15"
Wolf Canyon	1.25"	1.90"	1.71"	0.61"	1.23"	2.47"	3.16"	0.15"
Carrizozo	1.04"	1.40"	2.45"	0.64"	1.62"	0.26"	2.51"	0.14"
Luna Ranger Station	0.66"	2.25"	0.50"	0.01"	1.34"	0.88"	1.69"	0.10"
El Morro	0.68"	1.68"	1.00"	T	1.70"	0.85"	1.60"	0.00

Figure 9. Comparing precipitation for selected sites throughout central and northern New Mexico during June in years when a moderate to strong El Niño was beginning to 30-yr June climatological averages.

JUNE

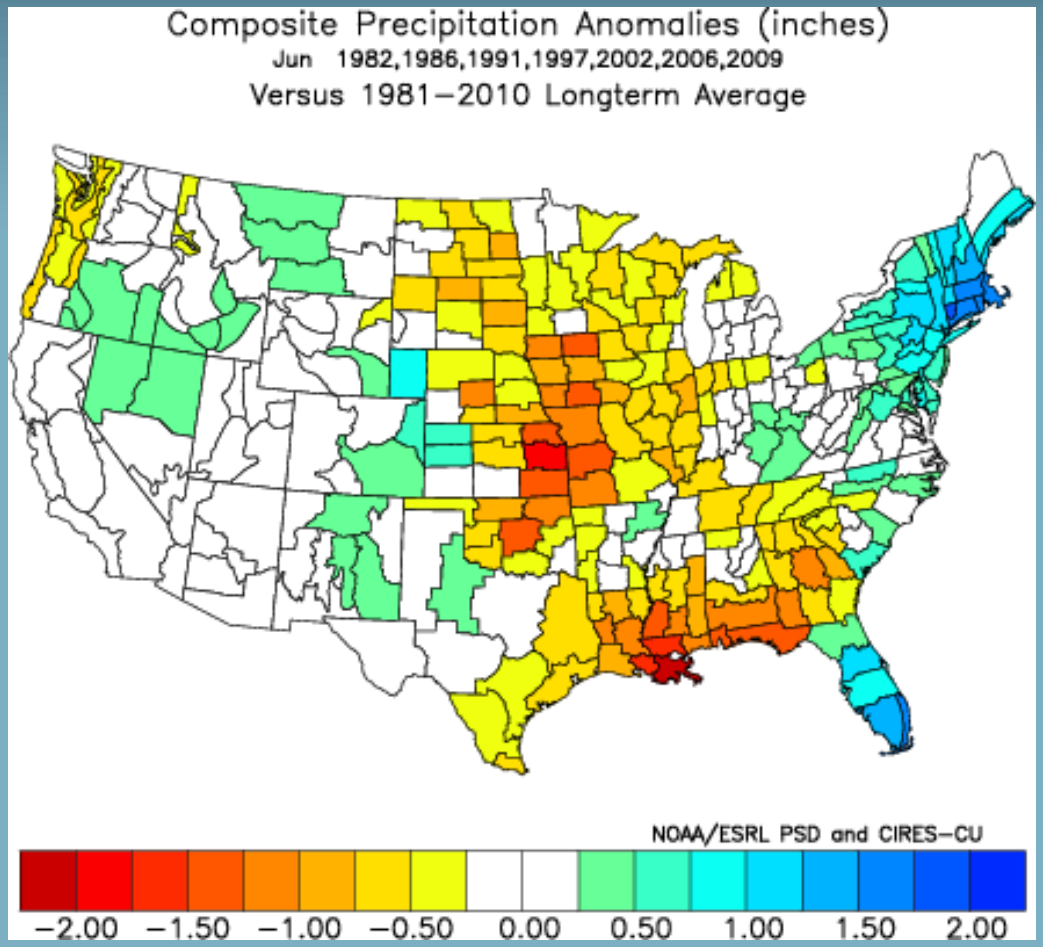
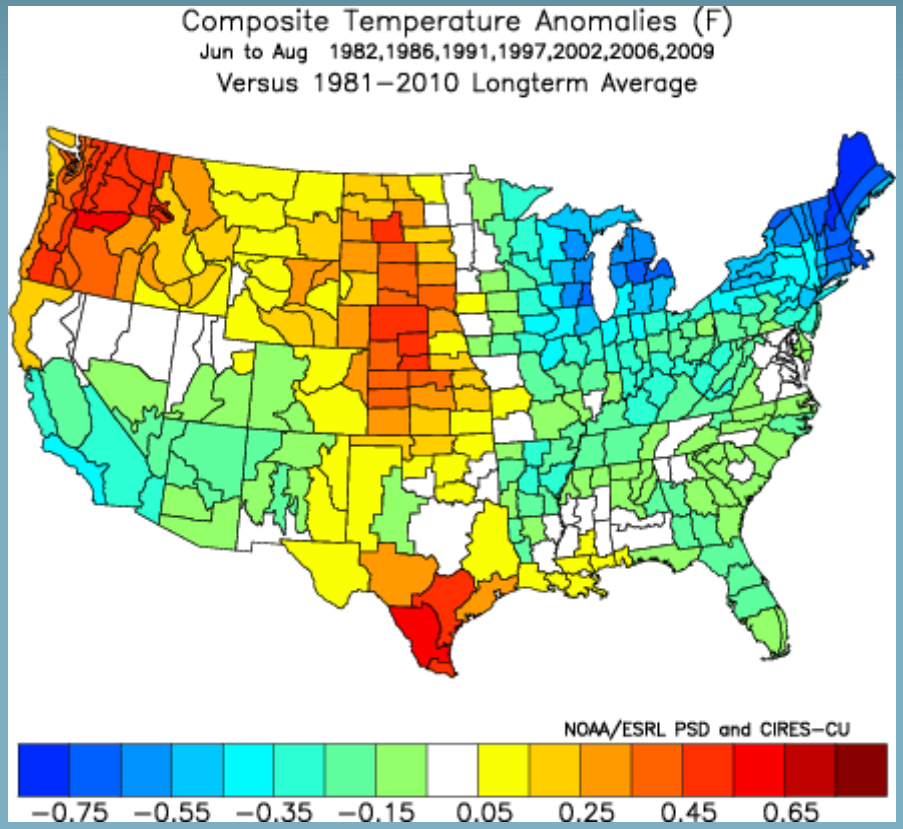


Figure 10. June precipitation anomalies during moderate to strong El Niño years since 1980. Locations along and east of the central mountain chain are favored for slightly above average precipitation in June and that's exactly what we've been experiencing during the first part of June 2014.

WHAT ABOUT TEMPERATURES?



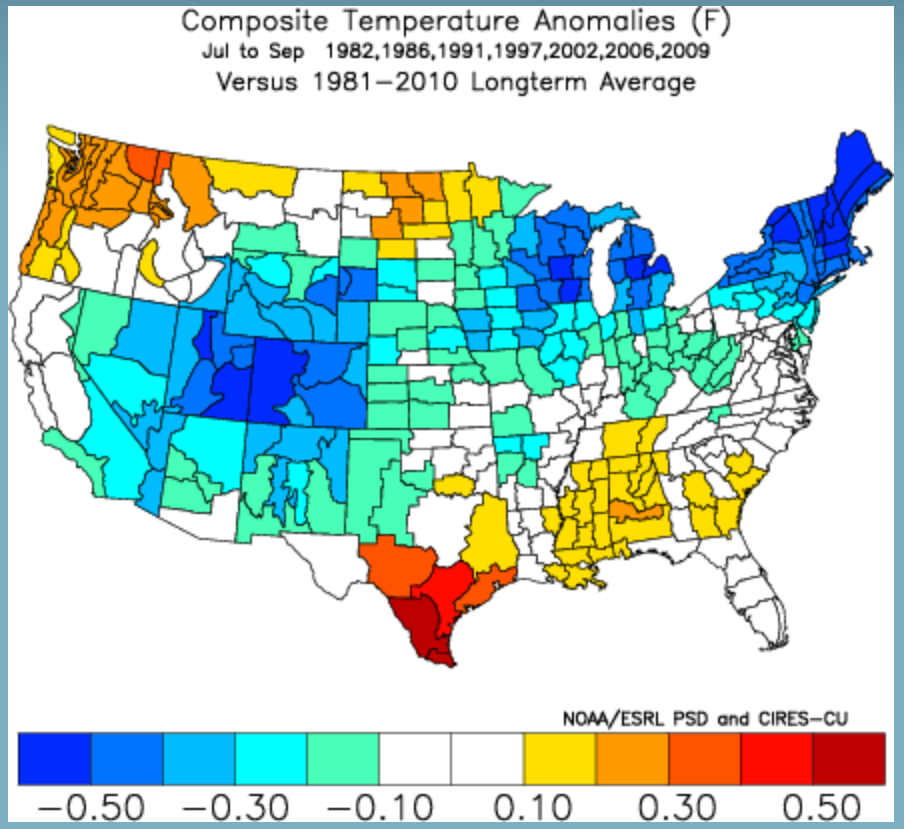
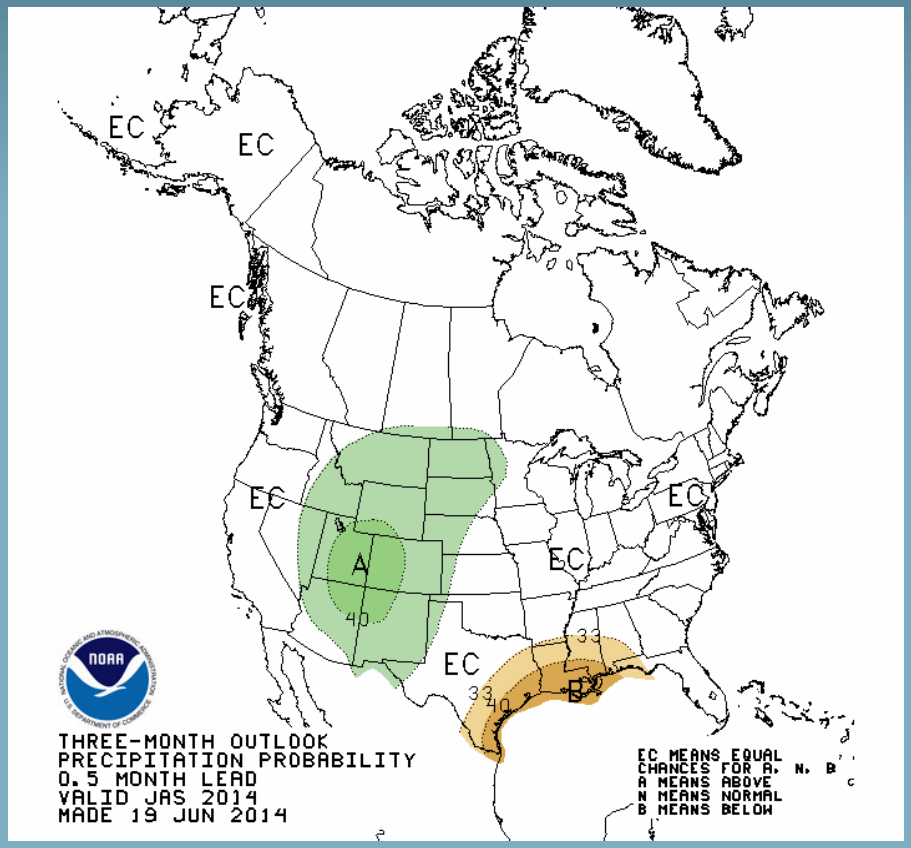


Figure 11. June to August average temperature anomalies during moderate to strong El Niño years as well as July to September temperature anomalies. Overall, summer seasons (Jun-Aug) during developing El Niño events are slightly cooler while the core of the monsoon season (July-Sept) is slightly cooler to cooler than average.

IMPORTANT LINKS BETWEEN MODERATE AND STRONG EL NIÑO YEARS AND THE NAM SINCE 1980

- *Current sub-surface ocean temperatures in the equatorial Pacific are nearly identical to May/June 1997. All coupled oceanic-atmospheric models are predicting continued warming with a moderate to perhaps a strong El Niño developing by mid to late summer 2014.*
- *1982 is the only other year since 1980 which somewhat resembles current sub-surface SSTs in the equatorial Pacific Ocean and therefore was used in this study.*
- *Moisture flux from the Ocean surface to the atmosphere is a major contributor to increased surface dewpoint temperatures over far northwest Mexico and the southwestern U.S. throughout the monsoon season. Lavin` et al. 2003 showed that the Gulf of California is strongly affected by El Niño and that warmer than average sea surface temperatures (SSTs) are the end result. Warmer than average SSTs create increases in sea surface elevation which in turn, lead to increased low level moisture evaporation as more water is exposed to the atmosphere with the potential of moving northeastward into New Mexico.*
- *During the 1997-98 El Niño, the entire Pacific Ocean basin was the warmest on record.*
- *As was the case in 1982 and 1997, strong El Niño events can result in higher than average SSTs in the Gulf of Mexico which in turn, can lead to more moisture availability from this body of water in addition to the Pacific Ocean moisture increase (Figure 7).*
- *Early onset appears to be a key determining factor in spring and early summer seasons (Higgins et al. 1998). When El Niño got off to a late start and remained weak, as was the case in 2004, the wettest portion of the monsoon season (July 1 through Sept. 15.) was well below 30 year (1981-2010) climatological averages.*

CLIMATE PREDICTION CENTER'S JULY-SEPT. OUTLOOK



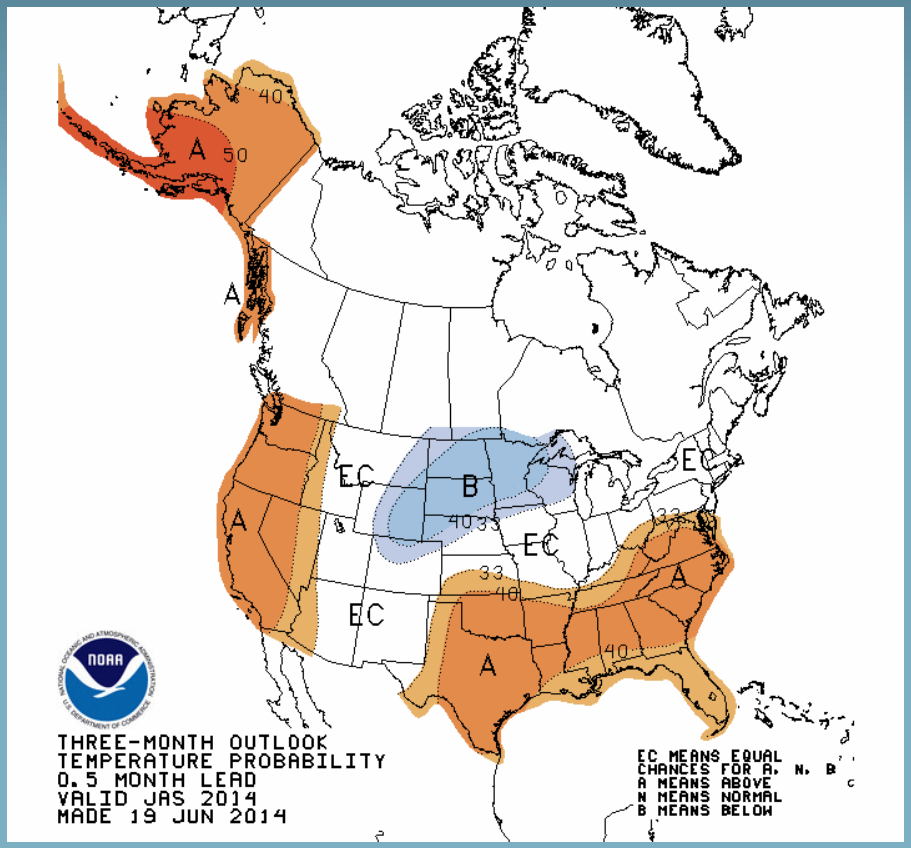


Figure 12. CPC's July-September 2014 outlook using dynamical weather prediction models as well as climatological statistics. The greatest probability for above average precipitation is centered over the four corners. Equal chances for either above or below normal temperatures are forecast for all of New Mexico.

WHY DO WARMER THAN AVG. SSTS IN THE EASTERN PACIFIC OCEAN RESULT IN GREATER CHANCES FOR ABOVE AVERAGE PRECIPITATION DURING THE MONSOON SEASON?

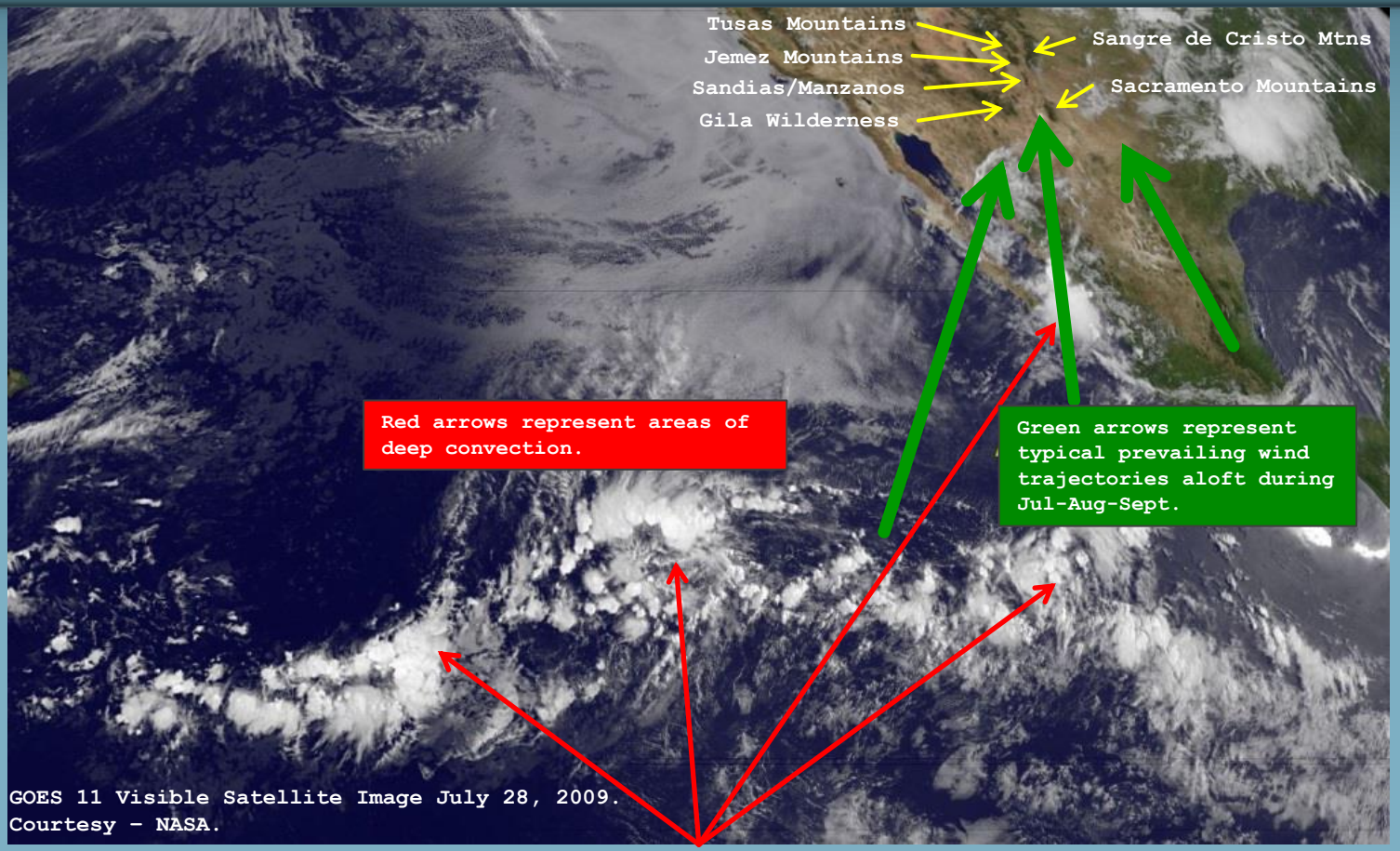


Figure 13. Anomalously warm waters associated with El Niño and a positive/warm PDO often result in increased tropical and subtropical convection in the far eastern Pacific Ocean. This increased moisture can be drawn north and northeastward with a prevailing southerly or southwesterly flow aloft, by definition, the NAM. A strong El Niño can also lead to increased Gulf of Mexico convection/moisture as in 1997 (Fig. 8).

IT'S ALL ABOUT THE SSTS

- If Hurricane Amanda and Cristina are any indication, things are certainly looking up with regard to low level moisture availability in one of the primary source regions for NAM moisture, the far east-central Pacific Ocean.

- Note: Hurricane Amanda strengthened to a Category 4 hurricane, the strongest May hurricane in recorded history in the eastern Pacific Ocean Basin! Cristina has also reached Category 4 intensity as of June 12, 2014.

Figure 14. Infrared satellite image of Hurricane Cristin in the eastern Pacific Ocean. June 12, 2014 9:30 AM MDT.

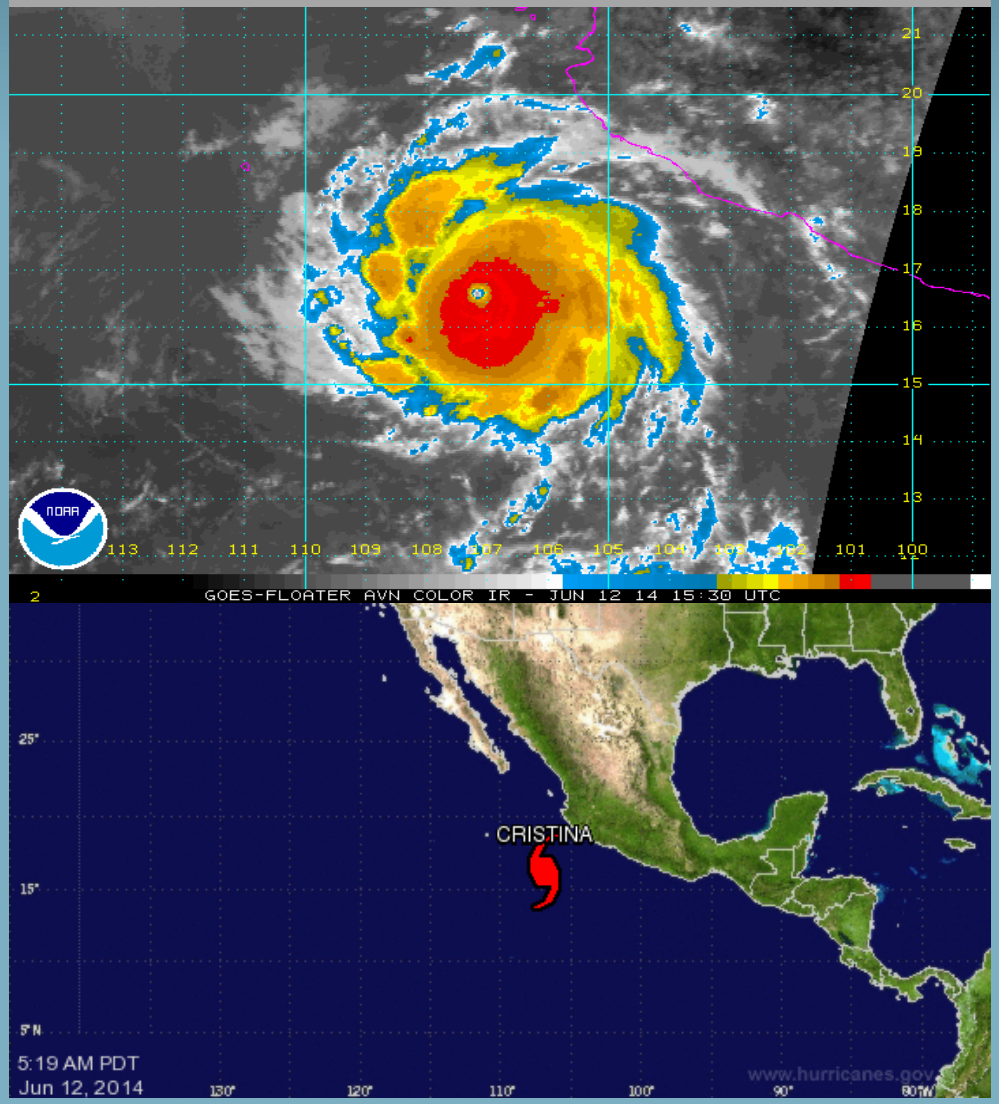
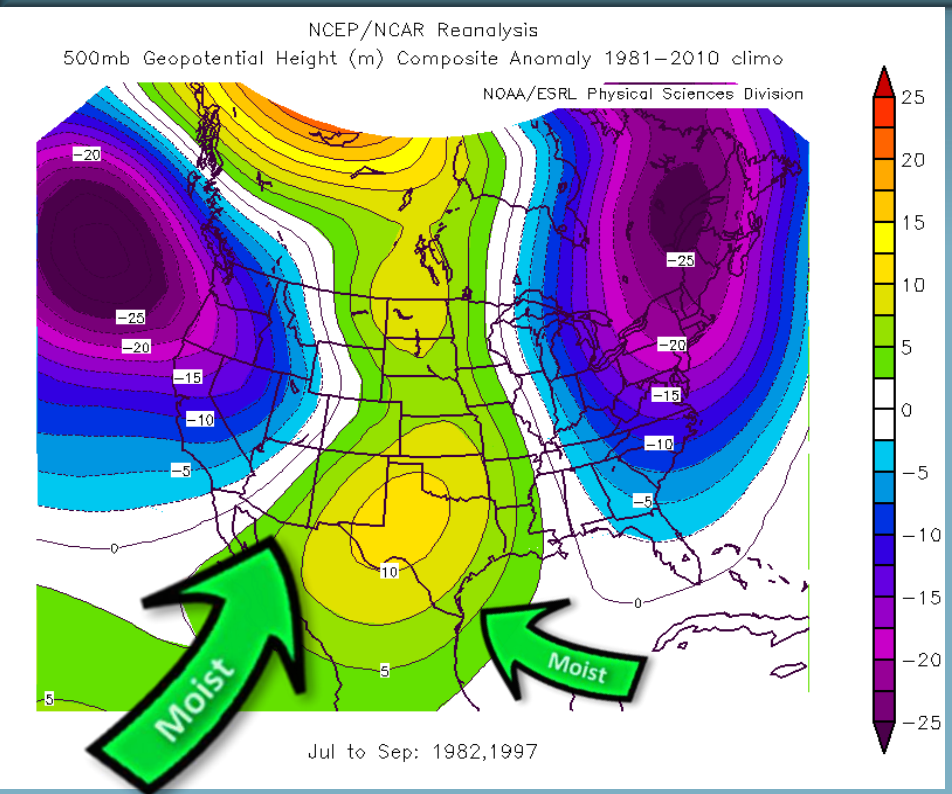


Figure 15. East Pacific Overview plot of Hurricane Cristina's location at 5:19 AM MDT 06/12/2014.

HOW IS IT THAT NEW MEXICO FAIRS WELL DURING JUL-SEPT WITH BOTH WEAK-MODERATE , MODERATE AND STRONG EL NIÑO EVENTS?



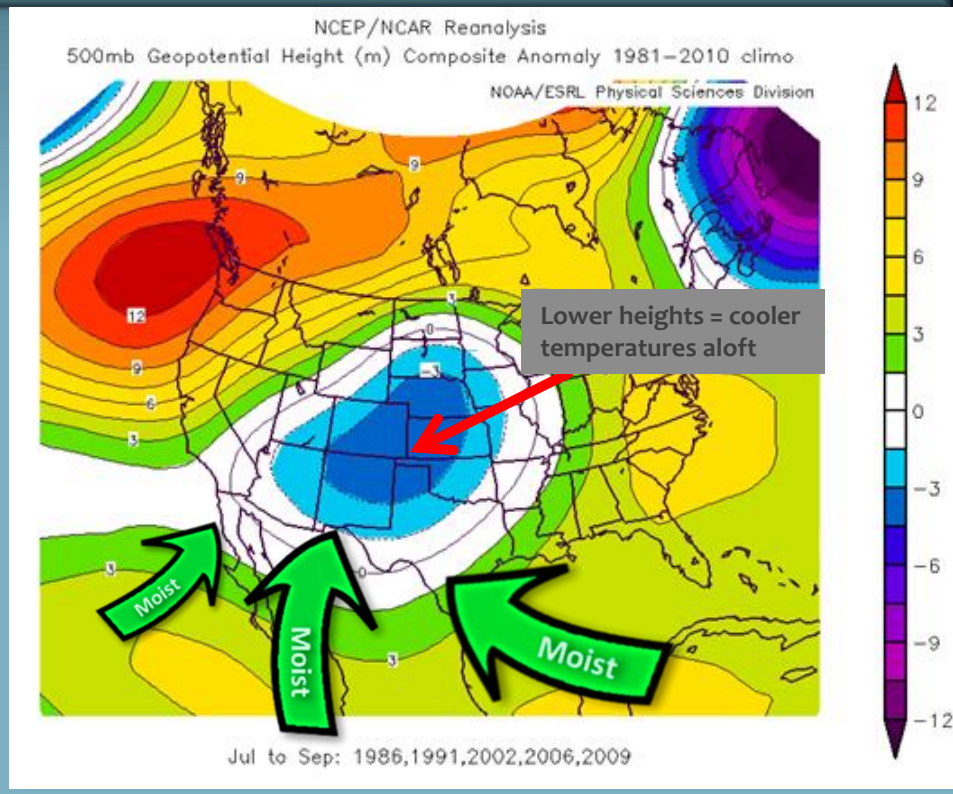


Figure 16. 500mb Geopotential Height Anomalies comparing strong El Niño onset years (1982, 1997) with weak-moderate to moderate El Niño events (1986, 1991, 2002, 2006, 2009). The two strong El Niño events since 1980 resulted in a stronger upper level subtropical high, displaced farther south than average, along with a stronger/deeper than average upper level low over the Pacific Northwest and a strengthened monsoonal/southerly flow over AZ and western NM. Average heights during weak-moderate to moderate onset years ended up with a weaker than average subtropical/four-corners high and Pacific Northwest upper low which would result in a weaker monsoon circulation but greater instability over NM as temperatures aloft would be slightly cooler than average. These plots may help explain why many portions of NM can end up with above average Jul 1 thru Sept 15 precipitation during both scenarios and portion of AZ can end up with below average precipitation given the weak-moderate to moderate El Niño events.

SUMMARY

- Precipitation in previous monsoon seasons during the onset year of a moderate to strong El Niño event were above to well above 1981-2010 climatological averages at sites throughout northern and central New Mexico.

- Data from the previous 7 onset years of moderate to strong El Niño events suggest that if current SST trends in the Pacific Ocean basin continue into late this Spring and early Summer, the probability for above average July 1 – September 15, 2014 precipitation is greater to much greater than average.

- If for some unforeseen reason a moderate to strong El Niño does not materialize or is slow to develop, chances for an above average monsoon season precipitation decrease and the probability for below average precipitation increases. This does not appear to be the case, however, with recent SST anomaly trends indicating a climatologically early onset.

- Why not use any of the coupled (atmosphere-ocean) climate prediction models including NOAA/NCEP, NOAA/GFDL, IRI, NCAR, NASA, and Canada's CMC in this study? While these models are vastly improved, only two of the models have skill (accuracy) scores for any portion of New Mexico in July, August and September of greater than 30%. The GFDL and NASA models show the most skill with regard to predicting precipitation in New Mexico during the monsoon. The remainder of the models have skill scores during the monsoon of 10% or less.

- Note: PDO index values are used to reflect current large scale SSTAs in order to evaluate seasonal moisture availability from the northeast Pacific Ocean and not to forecast long-lived PDO phase changes.

OUTLOOK INFORMATION

- *Outlook provided by National Weather Service Forecast Office Albuquerque, NM.*

- *For further information contact Andrew Church: andrew.church@noaa.gov (505)244-9150*

- *Citations/References for studies mentioned:*

Higgins, R.W., K.C. Mo, Y. Yao, 1998: Interannual Variability of the U.S. Summer Precipitation Regime with Emphasis on the Southwestern Monsoon. J. of Climate, 11, 2582-2606.

Lavin, M.F., E. Palacios-Hernandez and C. Cabrera, 2003: Sea Surface Temperatures Anomalies in the Gulf of California, Geofis. Int. 42: 363-375.